CHARACTERIZATION AND MONITORING OF NON-AQUEOUS PHASE LIQUIDS

TECHNOLOGY DESCRIPTION

The Ribbon NAPL Sampler (RNS) is a continuous, direct sampling device that can provide detailed depth-discrete mapping of Non-Aqueous Phase Liquids (NAPLs) - liquid solvents and/or petroleum products in a borehole. This NAPL characterization technique uses a membrane system to deploy a hydrophobic absorbent ribbon in the subsurface. The system is pressurized against the wall of the borehole and the ribbon absorbs the NAPL that is in contact with it. A dye, sensitive only to NAPL, is impregnated in the ribbon and turns it bright red when the contaminants are contacted. Upon removal from the subsurface, the presence and depth discrete location of DNAPL is indicated by brilliant red marks on the ribbon. The RNS has been deployed using both direct push and drilled boreholes with diameters of 2" and larger in both the vadose and saturated zones. In FY 2000, a smaller diameter RNS was developed for deployment in 1.25" diameter boreholes, a common diameter of rods pushed by pneumatic hammer rigs such as the Geoprobe™. The ability to definitively detect dense NAPL using direct push techniques is advantageous because the methods are generally faster and less expensive than conventional drilling, and Investigation-Derived Waste (IDW) is minimized. The original development of the RNS focused on deployment with the cone penetrometer in 2" diameter boreholes, but because there are far more Geoprobe™ rigs (approximately 1,000) used in environmental applications than cone penetrometer rigs (less than one hundred), the benefit of a smaller diameter RNS is obvious. In addition to the smaller diameter RNS, an RNS has been fabricated for deployment in a fractured rock borehole, and will also deploy the RNS through sonic drill casing. The main thrust of work this year has been to expand the capabilities of the RNS for greater applicability at both public and private contaminated sites.

All of the Dense Non-Aqueous Phase Liquid (DNAPL) research and development projects at the Savannah River Site (SRS) are selected based on targets driven by site cleanup goals and local and regional regulatory requirements. The RNS is part of a coordinated package of innovative DNAPL characterization tools that have been developed and deployed. Each technology was carefully designed to:

- Unambiguously identify DNAPLs in the subsurface.
- Minimize secondary waste.
- Eliminate undesirable gravitational movement of DNAPLs.
- Minimize IDW.
- Mitigate similar types of collateral environmental damage inherent in addressing this complex environmental need.

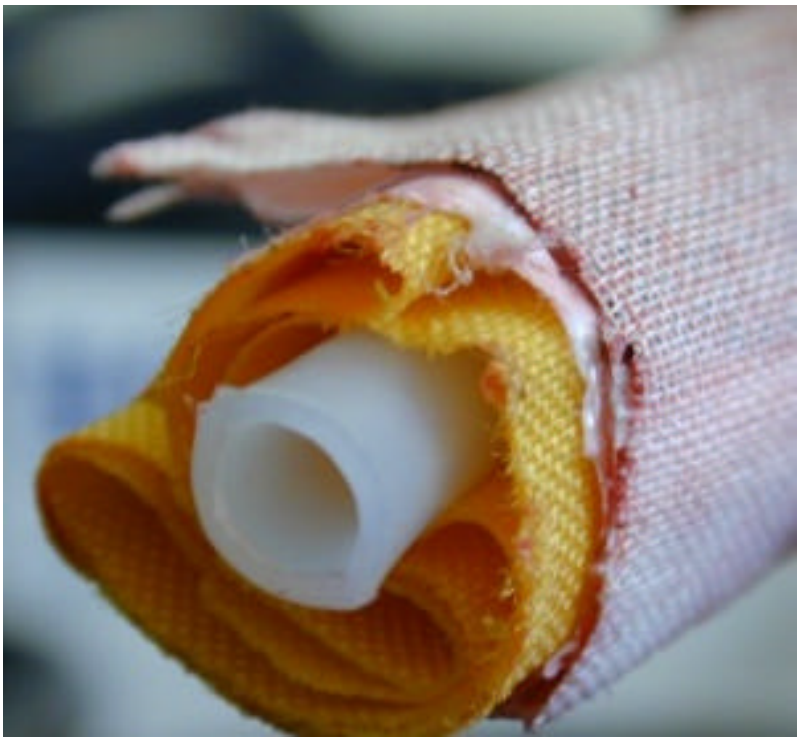
TECHNOLOGY NEED

Residual industrial solvents, primarily DNAPLs, are currently the most significant challenge for the successful completion of many large groundwater and soil cleanup efforts. Slowly dissolving DNAPLs provide a major source of groundwater contamination for hundreds of years. Adding to the challenge is the fact that DNAPLs are very difficult to characterize in the subsurface–especially when they are found in dispersed blobs as is typical at many sites. At waste sites where DNAPLs are suspected, robust characterization of the nature and extent of the contamination must be a key component of any comprehensive remediation strategy. Traditional sampling approaches generally are not successful at locating DNAPLs and a focused strategy based on an appropriate conceptual model should be used. Above the water table, residual DNAPLs will reside in intergranular pores held by capillary forces. Below the water table, DNAPLs behave in a complex fashion, moving downward as an immiscible phase and accumulating in highly concentrated discrete and dispersed ganglia. Because of the physical and chemical characteristics of DNAPLs, characterization and remediation methods that minimize unnecessary waste generation are prudent. Finally, precise delineation of DNAPL areas will facilitate the

design of appropriate remediation strategies and help keep cleanup costs from escalating. This work addresses the following STCG Need Statements:

- Characterization and Removal of DNAPLs and Light Non-Aqueous Phase Liquids (LNAPLs) from Soil and Groundwater OK99-01.
- Chemical Form and Mobility of Dense, Non-Aqueous Phase Liquids in Hanford Subsurface Transport of Contaminants RL-SS25-S.
- Dense Non-Aqueous Phase Liquid (DNAPL) Source Characterization, Containment, and Treatment ORHY-01a.
- Dense Non-aqueous Phase Liquid (DNAPL) Source Characterization, Containment, and Treatment ORHY-01b.
- Dense Non-Aqueous Phase Liquid (DNAPL) Source Characterization, Containment, and Treatment ORHY-01.
- Dense Nonaqueous Phase Liquids (DNAPL) Characterization and Remediation Technologies SR99-3017.

This is a FLUTe™ membrane recovered from a cone penetrometer hole. The dark (red) marks indicate the presence of Dense Non-Aqueous Phase Liquids (DNAPLs) at that depth.



Cutaway picture of Ribbon Non-Aqueous Phase Liquid (NAPL) Sampler suitable for deployment through direct push rods.

TECHNOLOGY BENEFITS

Many of the current baseline methods used for characterizing a suspected DNAPL site are described in Cohen and Mercer (1993). These methods generally consist of inferred measurements of DNAPLs (e.g., soil-gas analysis, geophysical methods), rule-of-thumb empirically developed methods for well samples, and direct measurements using invasive methods such as drilling and soil sampling. Most geophysical techniques do not have the resolution needed to detect DNAPLs occurring at scales of far less than one cubic meter. Conventional soil and liquid sampling are too costly and produce significant quantities of IDW.

The RNS was designed specifically for implementation using direct push access technologies. This minimizes the production of IDW. The RNS provides definitive evidence on the presence of NAPLs in the subsurface since it is not responsive to aqueous solutions. By allowing deployment of the RNS using a Geoprobe or other small diameter direct push rig, this broadly applicable DNAPL characterization technology is available for significantly more environmental projects.

The RNS has proved to be one of the most versatile and robust NAPL identification technologies. Because of the complexity of DNAPLs in the subsurface, however, all DNAPL characterization methods should be used in an ensemble approach where DNAPLs in an area are postulated with a probability determined from the weight of evidence of the data from several characterization techniques.

Red spots indicating contact with Dense Non-Aqueous Phase Liquids on Ribbon NAPL Sampler membrane recovered after deployment through cone penetrometer rods below water table.

CAPABILITIES/LIMITATIONS

By emphasizing safety and small-scale direct NAPL detection, the RNS provides accurate information about the precise intervals where DNAPL occurs, leading to optimized remediation design. The method enables continuous, direct sampling of DNAPLs and LNAPLs, provides immediate field results for the NAPL location and is easy to use. The method reduces waste and improves the precision of delineating DNAPL zones. The direct push methods are limited to unconsolidated sediments and to depth refusal of the CPT truck. One important limitation is that RNS investigations are only sensitive to the sediments in contact with the membrane.

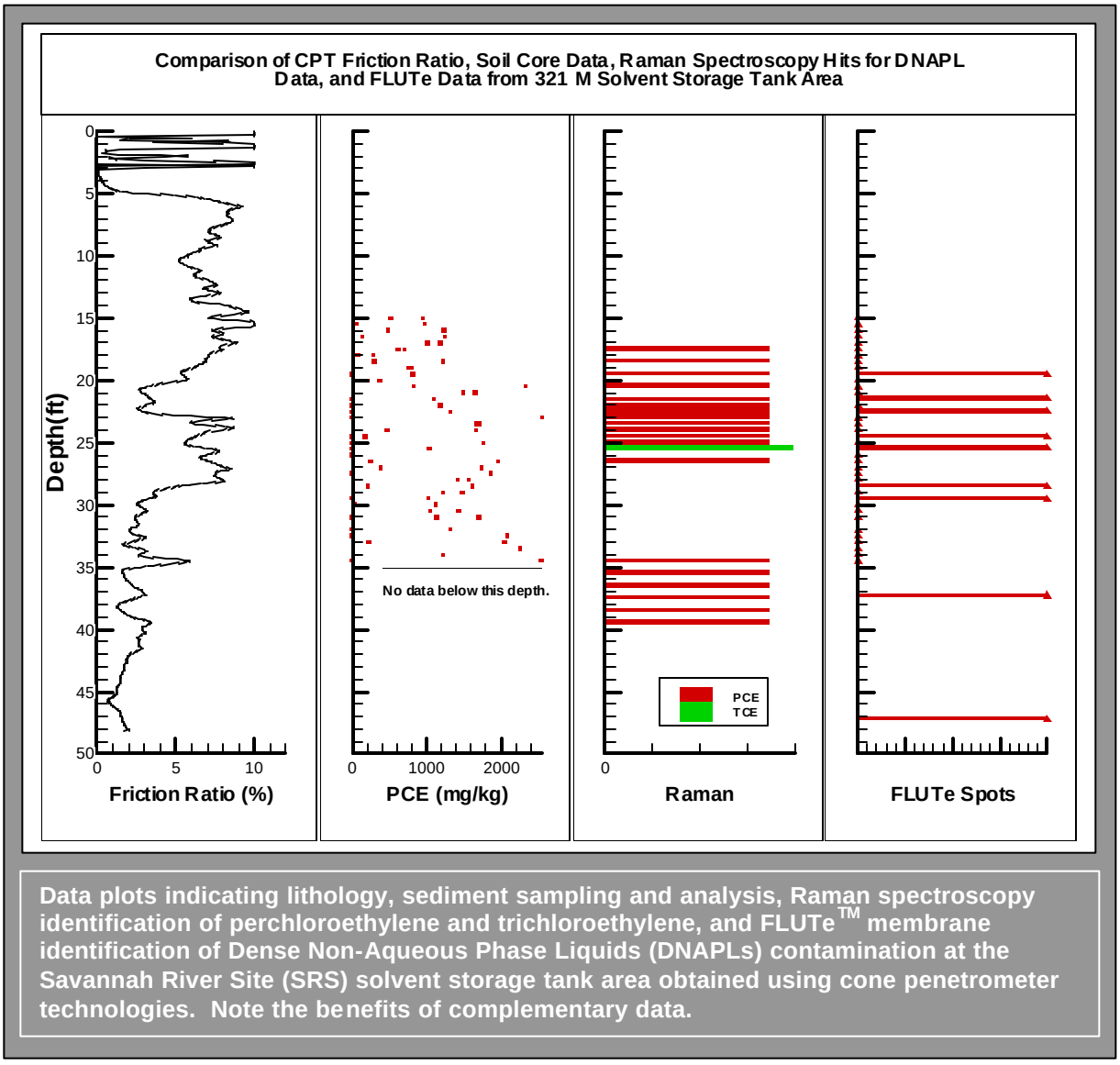
COLLABORATION/TECHNOLOGY TRANSFER

The RNS technology was developed in collaboration between scientists from the Savannah River Technology Center (SRTC) and Carl Keller of FLUTe™ Ltd. SRTC developed the original concept for the RNS then collaborated with Carl Keller on practical development details. FLUTe Ltd. is the manufacturer of the RNS and has made continuous improvements in the design and deployment procedures based on feedback from SRTC and other field experience. This relationship has been particularly advantageous to both parties as SRTC has been able to get prompt and updated supplies of the RNS and FLUTe Ltd. has sold the RNS to several other environmental professionals. To date, the RNS has been successfully used at three areas on the Savannah River Site, C400 area of the Paducah Gaseous Diffusion Plant, two areas at the Cape Canaveral Air Station, an Environmental Protection Agency Superfund site in Stockton, California, and Fort Meade, Maryland. A handbook is available on the technology titled “NAPL Characterization Using the Ribbon NAPL Sampler” by B. D. Riha and J. Rossabi (WSRC-TR-99-0259).

ACCOMPLISHMENTS AND ONGOING WORK

- First *in situ* direct detection of DNAPLs using RNS (membrane with dye-impregnated hydrophobic sorbent ribbon at SRS, Cape Canaveral Air Station, Paducah Gaseous Diffusion Plant, and U. S. Environmental Protection Agency Superfund site in Stockton, California.
- First *in situ* identification of perchloroethylene (PCE) and trichloroethylene (TCE) using Raman spectroscopy at SRS and at a Jacksonville dry cleaning site.

- Inferred detection of DNAPLs using Laser-Induced Fluorescence (LIF) at multiple wavelengths at several waste sites.
- Developed library of fluorescence excitation and emission spectra of likely DNAPL co-constituents.
- First deployment of alcohol micro-injection/-extraction test (PIX) through CPT for DNAPL detection at Cape Canaveral.
- Inferred detection of DNAPL using differential partitioning gas-tracer tests and quantitative limitations of this technique at SRS.
- First deployment of FLUTe™ (also known as SEAMIST™) membrane in a cone penetrometer hole.
- Development of DNAPL characterization course module.
- Deployment of RNS through sonic drill rods. FY 2000
- Fabrication of RNS for fractured rock borehole. FY 2000
- Fabrication and deployment of small diameter RNS suitable for Geoprobe boreholes. FY 2000



Data plots indicating lithology, sediment sampling and analysis, Raman spectroscopy identification of perchloroethylene and trichloroethylene, and FLUTe™ membrane identification of Dense Non-Aqueous Phase Liquids (DNAPLs) contamination at the Savannah River Site (SRS) solvent storage tank area obtained using cone penetrometer technologies. Note the benefits of complementary data.

TECHNICAL TASK PLAN/TECHNOLOGY MANAGEMENT SYSTEM INFORMATION

TTP No./Title: SR17C221 - Development and Deployment of Innovative DNAPL Characterization Methods. Related TTP No./Title.-.SR18SS32 - Applied DNAPL Characterization Methods; SR16C221 – SCAPS Logistics. The investigators on these tasks have collaborated successfully for many years and many useful technologies have emerged from these leveraged efforts.
Tech ID/Title: 237 - Innovative DNAPL Characterization Technologies
2238 - FLUTe™ System for CPT (Cone Penetrometer Technology)

CONTACTS

Joe Rossabi and Brian Riha
Principal Investigators
Westinghouse Savannah
River Company
Bldg. 773-42A
Aiken, SC 29808
(803) 725-5220 fax -7673
(803) 557-7807
joseph.rossabi@srs.gov
brian.riha@srs.gov

Sharon Robinson
Technical Program Officer
U.S. Department of Energy
Savannah River Operations Office
Road 1, Building 703A
P.O. Box A
Aiken, SC 29802
(803) 725-2378 fax: -3616
sharon.robinson@srs.gov

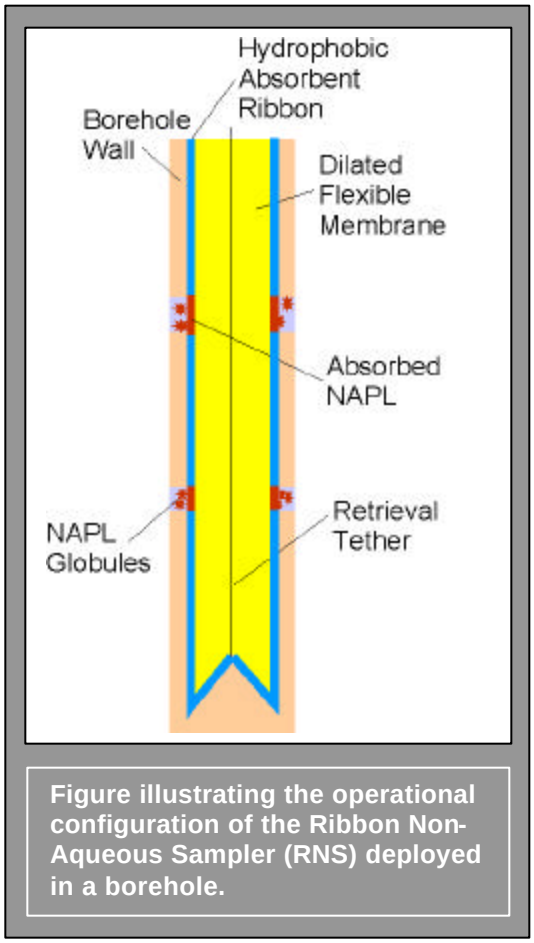


Figure illustrating the operational configuration of the Ribbon Non-Aqueous Sampler (RNS) deployed in a borehole.